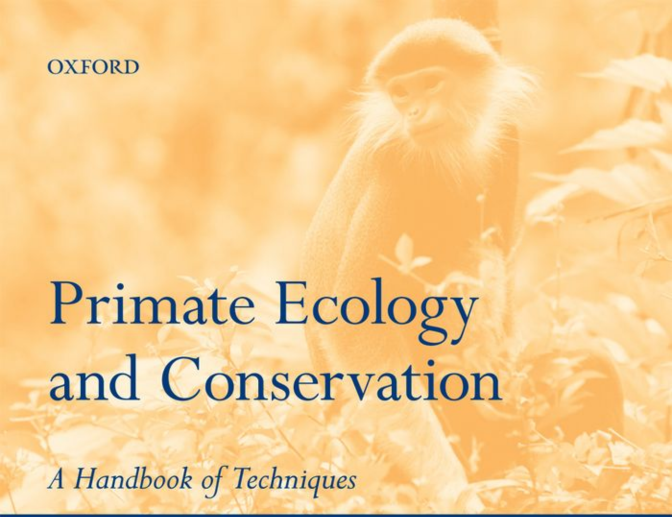

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Primate Ecology and Conservation

A Handbook of Techniques

ELEANOR J. STERLING

NORA BYNUM

MARY E. BLAIR

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Techniques in Ecology & Conservation Series

Primate Ecology and Conservation

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Eleanor J. Sterling, Nora Bynum, and Mary E. Blair

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Edited by
Eleanor J. Sterling
Nora Bynum
and
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Foreword

My first thought as I read this book in manuscript form was how much I wished it had been available when I was embarking on my own Ph.D. research more than 40 years ago. At that time, one simply gleaned what one could from the methods sections of published articles. To be sure, my supervisors offered me good advice and sound practical suggestions, like remembering to take a plentiful supply of pencils and a back-up pencil sharpener. The fact that *Primate Ecology and Conservation: A Handbook of Techniques* exists is helpful in itself, for it brings together so much information in one place. It is also testimony to the vastly increased sophistication of field techniques today.

My second thought as I read was how much I wished this book had been available when I, in turn, became the supervisor of my own students' research. Much more had been written about field techniques by then, and methodology was a far greater focus of attention, but still there was nothing like the *Handbook* to which I could direct them. It is a source of great pride and delight for me that two of those students, Eleanor Sterling and Nora Bynum, are editors of this volume and I can only hope they forgive me for any advice on pencil sharpeners I may have given them.

In selecting a field site and designing a research project, so much depends on context and the question asked. With many decades of experience and expertise under their collective belt, the distinguished contributors to the volume understand this well. Each chapter discusses the merits of a variety of techniques and approaches to the particular challenges of fieldwork, providing a lot of detailed and helpful information. But prescriptive statements are rare and few "correct answers" offered, which is as it should be. Even with the *Handbook* in hand, the researcher heading for the field will have many choices and decisions to make. Happily, those decisions will now be far better informed.

What strikes me above all, however, is the *Handbook*'s scope and ambition. It challenges all of us who study primates in the wild to explore research paths opening up almost daily, as a result of new technologies and conceptual advances in the biological sciences. Thanks to those developments, the distance between the lab and the field is shrinking steadily and research is burgeoning in recent, still "young" fields—from health and physiology to genetics and molecular biology.

The *Handbook*'s title proclaims its greatest and perhaps most important ambition. Decades of effort have largely, but not entirely, laid to rest the false dichotomy between research on the one hand and conservation on the other. The *Handbook* makes another, timely contribution to this endeavor. Discussions of ecology and conservation, and of science and action, are interwoven throughout, and the last three chapters bring the focus directly to conservation in the wild, captive breeding, and the scourge of international trafficking. The *Handbook* is as important in this regard as it is valuable to anyone setting forth to study our closest relatives in the wild.

Alison Richard
Yale University, July 2012

Preface

In this book we provide a comprehensive source that outlines major techniques in the study of primate ecology and conservation. Our target audiences are early career primatologists and graduate students, as well as established researchers and conservation professionals embarking on new research or conservation projects. Our synthesis focuses on new and emerging field methods alongside a comprehensive presentation of laboratory and data analysis techniques, as well as key methods for determining conservation status and conservation management. Importantly, we also discuss data interpretation as well as guiding questions and principles for students and researchers to consider as they plan research projects in primate ecology and conservation.

This volume's particular focus is on innovative ways to study primates in a changing world, in recognition of the fact that in order for primatologists to continue studying primates, we must successfully implement studies that inform our understanding of primate biology as well as primate conservation. Thus, we incorporate consideration of conservation status and threats to primate populations throughout this volume where appropriate. We are donating part of the proceeds from this book to support capacity development for biodiversity conservation.

We are very grateful for the efforts of friends and colleagues who supported the preparation of this volume. The following individuals provided guidance, references, and editorial support: Javier Alvarez, Erin Betley, Rachel Booth, Hannah Burnett, Lindsey Desmul, Kevin Frey, Kevin Frey, Karen Kennea, Ned Horning, and Connie Rogers. Many others (including Susan Alberts, Pat Whitten, Jeanne Altmann, Karen Strier, Carel van Schaik, Diane Brockman, Alison Richard, Agustin Fuentes) helped us to find chapter authors and reviewers. We extend deep thanks to all of the contributors and chapter peer reviewers for their outstanding efforts, and to Alison Richard for writing the Foreword.

A special thank you goes to the series editor, William Sutherland, and Ian Sherman, Lucy Nash, Muhammad Ridwaan, and Helen Eaton of Oxford University Press for their enthusiasm, support, and guidance during the preparation of this volume.

The Editors

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1

Introduction: why a new methods book on primate ecology and conservation?

Eleanor J. Sterling, Nora Bynum, and Mary E. Blair

The field of primatology has a long and rich history, and methods used to study primate species have evolved considerably since Ray Carpenter's pioneering fieldwork in the 1930s (Carpenter 1935). Gone are the days when primatologists focused solely on the meticulous description of a particular population of primates (e.g., Devore 1965) without analyses grounded in ecological, and in particular socioecological, theory. Primatologists today, in addition to studying the traditional behavioral ecology and population biology, use tools and methods such as genome-level genetics, spatial bioinformatics and modeling, endocrinology, and epidemiology. And even within the more traditional areas of inquiry, such as behavioral ecology, methods for studying social networks, for example, are more sophisticated, in initial data collection as well as analysis (see Chapter 5).

In part because primate populations and habitats continue to decline, primatologists have inevitably become involved in conservation issues, either through the use of their data for conservation management or via direct action. The foundational text *Primate Conservation Biology* (Cowlishaw and Dunbar 2000) makes a particularly convincing argument for why primates are important conservation targets: they play a critical role in many ecosystems, serving as seed dispersers and seed germinators and at times as keystone species that play a critical role in maintaining community structure; they can often represent up to 50% of the total mammalian herbivore/frugivore biomass in forested habitats; primates can also be conservation targets, helping to guide specific conservation action through their role as landscape species, and they can be flagship species, garnering overall conservation attention. At the same time, studies of our closest relatives in the animal kingdom help us reflect on human biology and evolution. At the time of their publication, Cowlishaw and Dunbar (2000) tallied 200–230 species in the Primate order following Groves (1993), and identified 13% as endangered or

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critically endangered and 18% as vulnerable, following the 1996 International Union for the Conservation of Nature (IUCN) Red List of Threatened Species^{TM} (Baillie and Groombridge 1996; see Chapter 16). In 2012, the IUCN recognized around 400 primate taxa (including both species and subspecies) of which 30% are categorized as endangered or critically endangered, and 19% as vulnerable (IUCN 2012). This increase in the percentage of primate populations categorized as threatened with extinction might be real, or it might be related to increased attention and work being done in the field of primate ecology and conservation, or it could also be related to taxonomic inflation. However, it remains clear that if primatologists wish to continue studying primates, we must successfully implement studies that inform both our understanding of primate biology as well as primate conservation.

This volume brings together a group of distinguished primate researchers to synthesize field, laboratory, and conservation management techniques for primate ecology and conservation into a practical empirical reference text with an international scope that is appropriate for graduate students, researchers, and conservation professionals across the globe. Our synthesis focuses on new and emerging field methods alongside a comprehensive presentation of laboratory and data analysis techniques, as well as key methods for determining conservation status and conservation management. This volume's particular focus is on innovative ways to study primates in a changing world, including emerging methods such as non-invasive genetic techniques and advanced spatial modeling. In addition to synthesizing field and lab methods, we also discuss data interpretation, as well as important guiding questions and principles for students and researchers to consider as they plan research projects in primate ecology and conservation. We incorporate consideration of conservation status and threats to primate populations throughout this volume, where appropriate, encouraging the integration of ecological and conservation methods.

1.1 Organization of the book

Each chapter in this volume is meant to provide a brief overview of a particular topic, which includes the specifics of how to use key methods or refers readers to more detailed sources for the specifics of methods. Methods to assess primate population size, density, and abundance, as well as advice to overcome the difficulties of doing so for rare and nocturnal primates, are examined in Chapter 2. Chapter 3 outlines methods for the capture of non-human primates including darting, anesthesia, and handling, highlighting techniques that previously could only be performed in the lab, but now can be done in the field. Such techniques are crucial for research questions that require unequivocal identification, or for which non-invasive or laboratory methods are insufficient. Multidisciplinary approaches to identify health status and determinants of infectious diseases in wild primate populations are considered in Chapter 4. The tools described in Chapter 4 provide the opportunity for not only basic health monitoring of populations, but also the assessment of the impact of anthropogenic change on non-human primate health, as well as modeling of infection transmission in populations. Chapters 3 and 4 both discuss processes for collecting biological samples as well as issues related to research permitting and the development of ethical protocols.

Methods to understand primate behavioral ecology within groups are considered in Chapter 5, including emerging approaches such as social network analysis and the use of Geographic Information Systems (GIS) in behavioral studies, alongside more traditional but still critically important methods such as how to habituate a primate group. Chapters 6 and 7 discuss how to characterize primate habitats and distributions through direct assessment, advanced spatial modeling, and plant phenology. Chapter 6 is distinctive in its discussion of species niche modeling, which holds considerable promise for enhancing species research and conservation. The methods to assess plant phenology covered in Chapter 7 are essential to characterize temporal and spatial variation in the availability of plant foods, which inform research questions about primate diets, reproduction, grouping, ranging, and sociality.

Ethnoprimatological methods are covered in Chapter 8, including multidisciplinary approaches to measure overlaps between human and non-human primate resource use, and those used to navigate diverse cultural landscapes and to conduct ethnographic interviews. Chapter 9 presents methods to study the social and spatial relationships between primate groups, including inter-group encounters. This chapter is also quite relevant to the study of ranging patterns and space use within individual primate groups due to its focus on GIS including advanced spatial modeling. Experimental methods to study behavioral ecology both in the field and the lab are considered in Chapter 10. This chapter presents an important argument that studies in the field, in the lab, and in free-ranging captive settings can provide complementary insights into the functions and mechanisms of primate behaviors.

Approaches to analyze the mechanical and nutritional properties of the foods that comprise primate diets are discussed in Chapter 11, including methods to examine the diets of elusive primates through stable isotope analysis. Chapter 12 considers diverse techniques for the study of energy expenditure in primates including the measure of heart rate, body temperature, and the use of doubly-labeled water. Advances in non-invasive techniques to monitor and assess hormone–behavior interactions in the wild are discussed in Chapter 13.

Molecular genetic methods for the study of primate ecology, evolution, and conservation are examined in Chapter 14. This chapter highlights emerging approaches including landscape genetics, which integrates GIS with genetic analysis, and next-generation sequencing. Chapter 15 provides methods to build models for the study of demography, life history, and population dynamics, and addresses how these methods can be applied to risk assessment approaches for primate conservation.

Methods for determining the conservation status of your study organism(s) and for contributing to conservation action *in situ* are covered in Chapter 16. These encompass how to identify threats to populations and their magnitude, and the importance of working with local communities on conservation activities. Chapter 17 reviews captive breeding strategies and *ex situ* conservation management for species recovery and reintroduction, including cooperative breeding programs and species survival plans, as well as the important role of zoos in conservation education and primate research projects. Lastly, in light of the wildlife trade's threat to primate populations, multidisciplinary methods used to study populations that are heavily impacted are covered in Chapter 18, including protocols for household, hunter, and market surveys.

1.2 Getting started: key points of advice for planning a research project

Before launching into our chapters, we want to begin our volume by offering some salient points of advice for planning a research project in primate ecology and conservation. These points transcend a variety of research topics and cover: (1) field site selection, (2) permits and visas, (3) digital data collection, and (4) ethical considerations.

1.2.1 Choosing a field site

When choosing a field site to begin a research project, one of the most important considerations is whether to go to an existing, active site, or to establish your own site. Unlike students of primatology 30 years ago, students today may have the luxury of choosing among several active field sites. Although it is crucial to primate conservation as well as to our understanding of primate biology to establish more field sites, the availability of time and funding can limit a researcher's ability to invest in the logistics of setting up a new site. On the other hand, there may not be an existing site suitable to answer the research question(s) that you have in mind. In general, making the "right" choice about a field site will vary greatly depending on the goals of a particular project. Potential field sites vary from simple tent encampments, with little research infrastructure, to sites like La Selva Biological Station in Costa Rica, which has embedded GIS capabilities, many kilometers of groomed trails, and a dining hall that can accommodate more than 100 people.

In almost any case, your choice will be greatly informed by undertaking a short pilot study. A pilot study can either test methodology at a particular site or entail visiting several potential sites. A pilot study can be particularly useful to show funding agencies and academic committees that your project is feasible, since the first-hand experience of visiting a field site before beginning your research will inform you of crucial details that influence a project's timeline and budget: e.g., the extent of the trail system, site infrastructure, specific habitat characteristics, how well Global Positioning System (GPS) units work, relative abundance of the primate population(s), and how long it might take to get them habituated to the degree needed for your project. All of this information allows for more detailed planning of the timeline and budget of your full project; for example, a pilot study can help you to determine if you need one long field season of 1 to 2 years to complete your study, or if several shorter seasons of a few months each will be sufficient.

1.2.2 Permits and visas

Another key issue when designing a research project is lining up research permits and visas for international work. Coordination with international governments and research communities can take time, and we encourage researchers to begin the process of acquiring permits and visas several months ahead of your departure date (or more depending on the country). Specifics are discussed in Chapters 3, 4, and 8, but we want to emphasize here the importance of a head start, especially since many funding agencies require permits and visas in hand before granting funds for any given project. Also, when deciding on a field site for your research, understanding the permitting requirements for the site can be very important as especially challenging requirements can impact the ease of returning to a site year after year.

1.2.3 Digital data collection

A critical consideration when planning a study is how to collect data in the field in a way that will make for more efficient data analysis upon your return. Many primatologists still prefer writing by hand in field notebooks (using waterproof paper), but advances in technology have facilitated the use of digital data collection in the field. In Box 1.1, Michelle Brown offers some key points of

Box 1.1 Digital data collection in the field (by Michelle Brown)

Mobile devices

Advances in technology have facilitated the use of digital data collection in the field, allowing for vastly greater efficiency in data input and processing, and facilitating a faster timeline to analysis after returning from the field. There is an enormous range of options available with regard to mobile devices, including personal digital assistants (PDAs), smartphones, tablets, and handheld computers. New items become available every few months, so I do not attempt to list them all here. However, the following are several issues to consider when selecting a mobile device:

- **Size:** Should the mobile device be small enough to fit into a shirt pocket or cargo pocket? Larger tablet devices are widely available and work with a range of software programs, but generally require two-handed operation and limit the user's ability to simultaneously handle binoculars or other field equipment. Smaller devices, while more portable, have limited screen space that makes it more difficult to enter data.
- **Input:** Do you require a keyboard or a touch screen for data entry? Touch screens dominate the current tablet and cellular phone market, but can be difficult to see clearly under sunny skies. Keyboards or thumb-boards make it easier to enter data without having to spend a lot of time looking at the screen, which means you can spend more time observing your subject(s). Input method is also important when choosing software, as some programs work with only one entry method. Older Palm devices are not only limited to touch screens, but also rely on a unique writing system that takes some time for new users to learn.
- **Battery:** How many hours should the device last between charging bouts? Few devices have batteries that last for a full day of data entry. One way of working around this limitation is to select an older device with removable battery packs, which allows the user to swap an empty battery with a fully charged battery; in some cases, extended-life battery packs are also available. Alternatively, external batteries are available for some of the newer tablets and smartphones, as well as solar or manual hand crank battery chargers.
- **Platform:** Do you need to use a particular operating system, such as Windows Mobile, Android, Apple, Blackberry, or Palm? For instance, if you use FileMaker Pro on your laptop and would like to use FileMaker Go (the mobile version of Filemaker Pro) to avoid switching among software programs, you are limited to Apple mobile devices.
- **Price:** How much are you able to spend on mobile devices, software licenses, external batteries, and other accessories? While some of the older devices are less expensive through eBay and similar sites, they are often plagued with hardware

Box 1.1 *Continued*

and software problems for which manufacturers will no longer offer support. High-end systems provide comprehensive, ready-to-use solutions but require thousands of dollars. Between these options are mid-range solutions, such as smartphones or tablets, that nonetheless cost several hundred dollars.

Data entry software

Table 1.1 lists commonly used data entry software programs, excluding software that only works on desktops and laptops (i.e., which are not compatible with mobile devices). Many of these programs allow you to develop your own data entry forms, and generally do not require a powerful handheld device (i.e., inexpensive or low end units can often work). However, there may be limits on which versions of an operating system the software will work, and many mobile database programs vary in their compatibility with desktop applications.

Table 1.1 *The most widely used data entry software programs. (All websites accurate and accessible as of December 2012.)*

Program	An	Ap	Bl	Pa	Sy	Wi	Reference
FileMaker Go		X					<http://www.filemaker.com/products/filemaker-go/>
HandDBase	X	X	X	X	X	X	<http://www.ddhsoftware.com/>
Pendragon Forms	X	X		X		X	<http://www.pendragonsoftware.com/forms3/index.html
Open Data Kit	X						<http://opendatakit.org>
Pocket Observer						X	<http://www.noldus.com/the-observer-xt/pocket-observer
PTab Spreadsheet						X	<http://www.z4soft.com/windows-mobile-pocket-pc/ptab-spreadsheet/

An = Android; Ap = Apple (Apple iPhone/iPod/iPad); Bl = RIM Blackberry; Pa = Palm OS; Sy = Symbian; Wi = Windows (Mobile Pocket PC and Smartphone).

Accessories

Most primates live in the tropics, meaning plenty of heat and humidity—two conditions that are terrible for the majority of mobile devices, which are generally not waterproof. To protect your handheld device during data entry, a waterproof pouch is a must. A variety of hard cases are also available, but these do not allow the user to protect the device during data entry. Also, consider getting an anti-glare

Box 1.1 *Continued*

screen, which can help protect the screen from scratches, and makes a touch screen much easier to use, by reducing glare under sunny skies.

Many mobile devices now have built-in GPS receivers. Older devices are less likely to work under dense forest canopies, but the signal-to-noise characteristic of GPS receivers are constantly improving and newer models may function quite well even under dense canopy conditions. Some units will allow you to attach an external antenna or a USB GPS receiver to further improve reception.

Some users find it easier to enter data on a touch screen using a stylus. Fingertip models are useful for older devices and are less likely to be dropped or lost than traditional pen-shaped or -tipped styli. More recent tablet devices are not always compatible with point-tipped styli and require a spongier, finger-like stylus.

advice, describing the pros and cons of various digital data collection devices and software used for primatological research in the field.

1.2.4 Ethical considerations

Ethical considerations are fundamental in studies of primate ecology and conservation, especially in those focusing on endangered primate populations or human and non-human primate interactions (see Chapters 8 and 16). Before any study, researchers must get Institutional Animal Care and Use Committee (IACUC) and/or Institutional Review Board (IRB) approvals which ensure the ethical treatment of animal and human subjects in their projects (also see Chapters 3, 4, and 8). Moreover, members of the American Society of Primatologists (ASP) and the International Primatological Society (IPS), and researchers publishing articles in journals by these organizations, must agree to adhere to the set of principles set forth in resolutions and policy statements regarding the ethical treatment of non-human primates. Especially in studies of ethnoprimatology and in conservation management, researchers and practitioners may find themselves in complex situations where human and non-human primate needs and interests must be balanced.

1.3 Primate ecology and conservation in a changing world

Our focus in this volume is on innovative ways to study primates in a world where humans continue to change the habitats in which non-human primates live. The chapters that follow often include case studies that emphasize the use of emerging methods to understand the ecology of primate populations in changing or altered habitats. Thus, a key goal of this volume is to highlight the importance of the human dimension of non-human primate conservation and biodiversity conservation as a whole, as well as the multidisciplinary techniques that will be necessary to incorporate local knowledge, customs, and values into ecological and conservation research and practice. Multidisciplinary approaches are critical not only to improving the effectiveness and sustainability of conservation actions, but also to enhancing our understanding of the ecology of non-human primate communities and the systems within which they live.

2

Primate census and survey techniques

Andrew J. Plumptre, Eleanor J. Sterling, and Stephen T. Buckland

2.1 Introduction

Primates have been counted for more than 50 years as part of scientific research into their ecology, behavior, and conservation. Survey methods vary and have aimed to obtain measurements of either relative abundance (an index that is assumed to be related to abundance, such as encounter rate that is number of animals detected per unit distance), density (no/km^2), or total population numbers. Researchers usually want a measure of density, or its extrapolation to an estimated number of animals by multiplying by the study area, or total population size obtained from total counts, but in some cases this is simply not possible.

Estimating the numbers in a primate community is important for many fields of biology and many studies base their findings on the underlying population density or abundance of the primate species being studied. Understanding what processes limit primate populations, whether ecological or social, depends on knowing the population density and range sizes at any one site. Understanding some of the causes of variation in primate behavior often depends on knowledge of variation in rates of competition, which again is linked to primate density. Conservation of a primate species is very much dependent on knowing how many individuals there are globally as well as within individual populations. Understanding how disease impacts primate populations is again affected by primate density and abundance; there are many other examples. Unfortunately the methods that have historically been used to estimate primate densities and abundance have been varied in quality and the same mistakes have been repeated in numerous studies around the world, making it difficult to compare across studies and sites. This chapter aims to assess the current thinking about methods that can be used to survey primates as well as to point out some of the more common flaws that researchers regularly make.

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2.2 History of primate surveying

Initial survey methods were basic and generally involved trying to estimate a complete count of the population. For example, Schaller (1963) counted mountain and Grauer's gorillas (*Gorilla beringei*) using nest counts of different groups to estimate a total population size. These attempts to make complete or total counts can work in certain situations but are usually impractical. During the 1970s Struhsaker investigated line transect sampling methods to survey primates in Kibale Forest in western Uganda (Struhsaker 1975, 1981). The methods he developed have been built on elsewhere around the world and the "line transect" survey method is now the most commonly used method to count primates.

Struhsaker's work in the Kanyawara study area of Kibale looked at the ecology, ranging, and behavior of several primate species. A network of trails was established at 100 m intervals in a grid across the study area and some of these trails were used to census the primate species. The degree to which trails were selected at random for the surveys is unclear. When walking the trails he (or his assistants) measured the distance from where the observer first sighted a primate group to the group itself—the *animal–observer distance*. Subsequently, as line transect methods were developed in the 1970s, it became clear that the *perpendicular distance* was an important measurement to be taken. Struhsaker had plotted sightings of the primates on maps of the trail system while undertaking the surveys, so he made an estimate of perpendicular distance by measuring from the maps afterwards (Struhsaker 1975). Based on his knowledge of the number of primates in habituated groups in the study area he found that the *animal–observer distance* measurement provided more accurate estimates of the known numbers than the *perpendicular distance* measurement, which he found tended to overestimate the population size. As a result the *animal–observer distance* has been promoted in primatology for the last 30 years as the measurement that should be taken (Struhsaker 1981). Only one other paper published around the same time tended to promote the *perpendicular distance* method and examined several variations of this method (Whitesides *et al.* 1988).

At the same time, the field of what is now referred to as "*distance sampling*" was being developed in other disciplines, notably zoology and wildlife management, with the underlying mathematics and assumptions of the methods being assessed and tested (Burnham *et al.*1980; Buckland *et al.* 2001). These methods used *perpendicular distance* methods to estimate densities of various animal species and showed that they were fairly robust and accurate when tested. These are now used to estimate the abundance of populations of species as diverse as whales, songbirds, moose, and chameleons. However, primatology has been slow to adopt these methods because of the history of census methods in this field.

There are several reasons why Struhsaker's (1975, 1981) measurement of perpendicular distance may have failed to estimate the "true density" of primates. These include taking measurements from plots on maps rather than measurements in the field, the fact that it was unclear whether he measured to the center of the group or the first animal seen (a high proportion of zeros in his perpendicular distance estimates suggests the latter), whether his estimate of the "true population" was accurate in that it included lone males that move around the periphery of groups, sampling design, and whether his animal–observer distance estimates were accurate because they were estimated by eye. In a later paper, Mitani *et al.* (2000) showed that there can be great variation between observers in their first sighting of primates in Kibale and the animal–observer distances measured, and that you cannot compare observations between different observers because of this. This finding questions the usefulness of the method because you can only compare densities obtained between sites or over time at the same site *if* the same observer has collected the data. However, a more recent paper has also shown that the method used to analyze animal–observer distance measurements in primatology is incorrect and that there are many reasons not to use this method (Buckland *et al.* 2010a). We will therefore focus on the perpendicular distance measure in any reference to the line transect method in the rest of this chapter.

There are still several issues that complicate the use of line transect methods when estimating primate abundance and as a result other methods have also been developed. These include the lure count method (which is based on distance sampling theory), plotting calls of groups to estimate densities for some species that call reliably, and genetic sampling of populations for total counts or capture-recapture estimates. The rest of this chapter focuses on the various methods that can be used to survey primates and the issues to be aware of in each method.

2.3 Total count methods

Total count methods are used in very specific situations. These are: (1) when the area to be surveyed is relatively small so that the whole area can be searched, (2) the species can be easily found and identified, (3) the number of animals to be counted is not more than about 500, and (4) individuals or groups can be recognized and separated from others. Mountain gorilla (*Gorilla beringei beringei*) and cross-river gorilla (*Gorilla gorilla diehlii*) surveys have used total count methods because the forest areas are relatively small, the numbers of animals are limited, and each group can be aged and placed into sex categories using dung size and hair found in night nests (Gray *et al.* 2009; Sunderland-Groves *et al.* 2009; Weber and Vedder 1983). In general the method uses a sweep count involving several teams that search for a fresh gorilla trail throughout an area and when they find it follow the trail to count three consecutive groups of night nests. Size of dung in the nests is measured and the nests are searched for signs of silver hairs, indicating an adult male. Nest locations are plotted on a map of the survey area using GIS and any similarly sized groups are compared for their composition; if they are too similar to be separated they are assumed to be the same group. Until recently no independent verification had been made of this method and it suffered from the fact that there was no good measure of the probability of detection of the groups or how well groups are separated or combined. Guschanski *et al.* (2009) compared the total count in Bwindi Impenetrable National Park with the genetic identification of individuals from dung collected in the night nests during the census and showed that the total count method had overestimated the population by 10% because individuals can make more than one night nest during the night and because lone males were double counted.

2.4 Genetic methods of surveying

With genetic analysis costs falling and the ability to identify individual animals improving, the use of genetic methods to survey primates is being tested under two general approaches: (1) the equivalent of a total count of the population where individuals are identified from DNA extracted from feces (e.g., Guschanski *et al.* 2009) or hair samples (Goossens *et al.* 2005) and (2) genetic capture-recapture analysis (e.g., Arandjelovic *et al.* 2011). In the first method many of the prerequisites of the total count method are needed, in that the population must be small in order to be able to genetically identify all individuals, the whole area must be able to be surveyed relatively easily, and it must be possible to find all individuals. Genetic capture-recapture is very new for primate surveys and is still being tested. However, it has been used for the past 10–15 years fairly effectively for elephants (Eggert *et al.* 2003), coyotes (Kohn *et al.* 1999), bears (Mowat and Strobeck 2000; Paetkau 2003), and otters (Dallas *et al.* 2003) amongst other species. For a list of software programs to implement the use of genetic data in population surveys, see Chapter 14.

2.5 Line transect methods

Line transects have been the main method used to survey diurnal primates. This is because they can be used to cover long distances relatively quickly and good methods have been developed to analyze the data. Distance sampling methods are an extension of strip plot methods. In the latter, long thin plots of fixed width are searched during surveys, ensuring that all animals within the plot are found. This method tends to have low sample sizes because the strips need to be relatively narrow (about 10–15 m either side of the transect line for primate surveys in forests) in order to be sure no animals are missed. By measuring perpendicular distances from the transect, a larger strip width is possible and a correction can be made to allow for the decrease in detectability of animals with distance from the transect. The free availability of the software Distance (Thomas *et al.* 2010) has made it far easier to undertake the analyses needed. However, for these methods to work, a minimum of 30–40 sightings of groups are needed to obtain an estimate around the true density and it is better to have 60–80 sightings to minimize the error around the estimate (Buckland *et al.* 2001). If these cannot be achieved with sufficient transect lines (see survey design below), or by repeated walking of the transects, then other methods need to be investigated. It is therefore important to make a pilot test of the method in the study area, before investing too much in the survey, to determine if the encounter rates are too rare to be able to estimate a density. If no method works well it may be necessary to estimate relative abundance or occupancy only (Section 2.7). Line transect methods have four key assumptions:

1. *Objects on the line are detected with certainty*. Therefore, search effort should be concentrated around the line. For primates in tropical forest, which can be 30–50 m high, this means having one observer focus on the canopy above the line while another searches the sides. Van Schaik *et al.* (2005) found that searching plots for nests of orangutans tended to provide more accurate estimates than line transect methods because observers were missing nests on or near the line.
2. *Objects do not move before detection*. If responsive movement occurs, every effort should be made to record the position of detected animals prior to responsive movement. Observers should also endeavor to move quietly, to minimize responsive movement. Non-responsive movement does not generate large bias provided it is slow relative to the speed of the observer. This means that the observers must move at a speed that is relatively fast. Historically survey methods have recommended that observers move at about 1 km/hr to make sure they do not miss primates, but if the average speed of the primates is also around 1 km/hr or faster, substantial upward bias in density estimates can be anticipated.
3. *Measurements are exact*. Many primate surveys estimate distance by sight and the accuracy of these measurements has been shown to be poor (Buckland *et al.* 2010b). There is no excuse, when tape measures and range finders are easily available, to undertake surveys using visual estimations only.

4. *Animal locations are independent of the transects*. This assumption can be effectively ignored if a good sampling design is used when establishing transects (see Section 2.5.1).

There are, however, still several issues that complicate line transect estimates of primate density and which need to be thought about before conducting any survey and we address these here.

2.5.1 Sampling design

A critical issue, which is a flaw in many primate surveys, is the sampling design. When you read the primate literature you will often see surveys conducted along a transect that forms four sides of a square. It is usually assumed that each of the sides is an independent transect and that four transects have been walked. However, they cannot be independent when they are connected in a square shape and effectively only one transect is being walked. There are also problems because at the corners the observer is sampling the same area twice. We refer readers to statistical- and ecological-methods textbooks for more on sampling theory, and to Buckland *et al.* (2001) and Strindberg *et al.* (2004). Basic principles of survey design should address two key issues to infer reliable population size estimates:

1. Transect placement should be random. In the case of simple random sampling, lines have an equal probability of being placed anywhere in the study area. The software Distance can be used to generate a sampling design for a study area and can be used to assess the probability of sampling any point in the study area (Strindberg *et al.* 2004).
2. Replicated transects—at least 10–20 transects (preferably nearer 20)—should be surveyed in each study area. We have seen survey designs where several transects have been surveyed but only one or two walked in each study area and then these different study areas compared for their different primate densities. Effectively the replication is too low in these studies to obtain a good density estimate for each site and therefore the comparisons are flawed.

An example of a good design for surveys of primates in Kalinzu and Maramagambo Forest Reserves in Uganda included surveys of all diurnal monkey species as well as chimpanzees (Fig. 2.1). Here the sampling design was made in Distance with 3 km transects placed using the systematic segmented trackline sampling option. The angle at which the transects were run was varied to assess which direction provided the most even probability of sampling each corner of the park and the north–south orientation proved to be the most balanced design (Wanyama *et al.* 2010). A similar process was used to design surveys for Kibale National Park

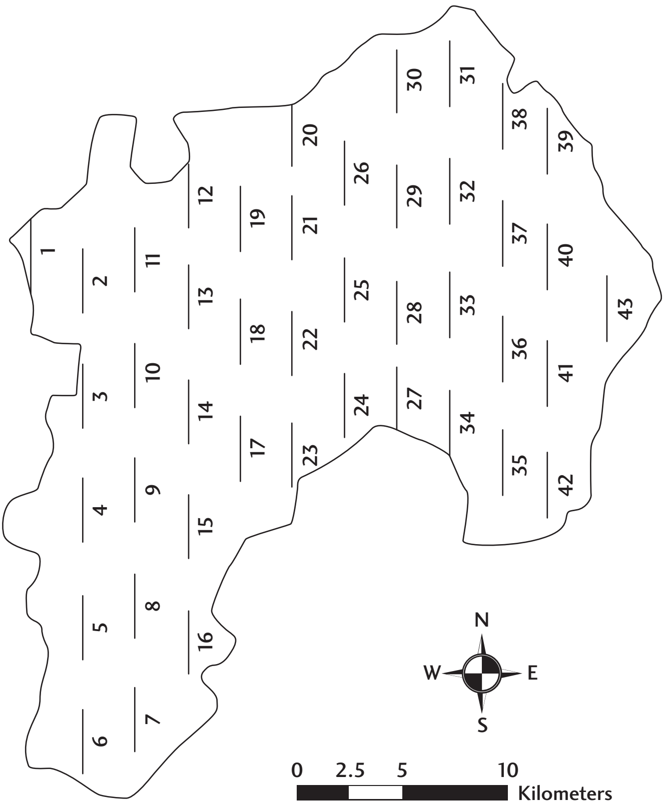

Fig. 2.1 Line transect sampling design for surveys of primates in Kalinzu and Maramagambo Forest Reserves, Uganda. The number of each 3 km transect line is given beside the line.

(Wanyama *et al.* 2010) and this design is now used by the Uganda Wildlife Authority for regular monitoring of populations of primates and other large mammal species.

2.5.2 Group versus individual density

Primates live in groups that can vary from 2–3 individuals up to several hundred individuals. However most primate species live in groups that number between 10–40 individuals. Dealing with groups and what you measure along line transects is tricky when making surveys of primates because different studies have used different methods and there has been no test of which method performs best. Studies measure perpendicular distances from the transect to the first individual seen, to the individual nearest the line transect, or to the center of the group

(Whitesides *et al.* 1988; Plumptre 2000). A complicating factor is that groups of monkeys can spread out over large distances and form subgroups 200–300 meters apart. If encountered along a transect, these subgroups are likely to be counted as different groups. This is fine if the subgroup size is measured at the time, but not if subgroup density is to be multiplied by an average group size in the final analyses, as this will overestimate the primate density (Plumptre 2000; Plumptre and Cox 2005; Buckland *et al.* 2010b). Buckland *et al.* (2010b) looked at various ways of dealing with subgroups/groups and give recommendations that vary depending on what can be observed when a subgroup or group is encountered. Options include: (1) measure to the center of the subgroup and ensure you can count the number of monkeys in the subgroup (all individuals must be counted, at least for subgroups close to the line); (2) measure perpendicular distance to each individual in the group seen. While time consuming, this method might be used if you are unable to detect all the members of a subgroup such that the subgroup size would be underestimated. However it cannot easily be used for species that occur in large groups/subgroups. One way to get around this problem is to truncate the perpendicular distance in the field and only record individuals within this distance of the transect. Other methods proposed by Whitesides *et al.* (1988) of measuring to the nearest individual and correcting by an average group spread, and by Plumptre and Cox (2005) of measuring to the center of the subgroup seen (but probably missing some members of the subgroup), are likely to produce biased results and should not be used.

2.5.3 Indirect sign surveys—nest counts and dung

Some species are very hard to detect from observations on transects as they flee and hide silently when they observe you coming. The great apes are among this category, and despite their large body sizes they can be remarkably elusive, partly because they are at low densities in forests and partly because they spend time on the ground and are hard to observe when there. However, apes build nests, both day and night nests, which can be counted instead of live animals. Dung can also be counted for some species and is often used for ungulate surveys where sightings of a species are rare; however its applicability for primates is poor and it has only been used for surveys of apes (Todd *et al.* 2008). These authors caution that seasonality and differentiation between defecation events and the number of dung piles produced can significantly affect the results. In the case of these indirect signs we need to assess two values: (1) production rate of the sign and (2) decomposition rate of the sign. For example, in the case of chimpanzee nests we need to know how many nests on average are constructed each day and the average time to decay for each nest. Chimpanzees can build more than one nest in a day but also sometimes reuse nests, so this nest decay and reuse needs to be measured at the site rather than assuming every nest is new, as is often the case. An advantage of the use of indirect signs is that they do not move and hence perpendicular distances can be measured easily and accurately.

Decay rates of nests can be highly variable. In Budongo Forest Reserve in Uganda chimpanzee nests decayed between 10–161 days (Plumptre and Reynolds 1996) while orangutan nests could take over 600 days to disappear (Mathewson *et al.* 2008), and it has been shown that decay rates vary with season and location (Plumptre and Reynolds 1996). The same is true for dung, even elephant dung (Nchanji and Plumptre 2001). This variability increases the 95% confidence limits of the population density estimate. One way to avoid having to calculate and use the decay rate is to use a method of marked nest counts where the transect is repeatedly walked at intervals within which no nest will decay, marking all nests and counting the number of new nests constructed over time (Plumptre and Reynolds 1996). This effectively measures the density of nests produced between the first and last walk of the transects and, by dividing by the time elapsed, can give the density of nest building individuals in the population. It is important to establish an order to walking the transects for marked nest counts so that there is a similar time period between the first and last walk of each transect and so that each transect is walked regularly within 10–15 days. The number of repeated walks depends on the number of nests sighted but one should aim to have at least 60 new nests constructed between the first and last walk of the transects. Although this method takes longer to implement, it is more likely to produce accurate and precise estimates than a method using nest counts that must be corrected for nest decay rates. This is because to truly correct for nest decay, nests should be monitored before and during the census period as well as over the whole study area. To do this will take as much time as carrying out a marked nest count. Most studies that correct using a nest decay rate obtain the decay rate by monitoring nests in one small part of the study area (with easy access) or else “borrow” a rate from another study site altogether. Both methods are unlikely to provide a realistic estimate of the true decay rate in the study area and will not obtain a good estimate of the population density.

2.6 Using group calls to survey primates

2.6.1 Surveys using regular calling by primates

Some primate species regularly call at a specific time of day. For instance gibbons (*Hylobates* spp.) make calls each morning for territorial defense and these calls can be heard over 2 km away (Brockelman and Srikosamatara 1993; Buckley *et al.* 2006). The calls can be used to map the territories of each pair and thereby estimate the number of pairs in a study region. Triangulation of calling pairs is usually made from listening posts by at least three observers at three locations recording simultaneously from dawn to about 10:30 am, at the same site over several days before moving to new areas. It is important that several days are spent at each observation post because some animals may not call on one day and may be missed as a result. Ideally, sightings should be made of calling pairs to assess if they have any young with them at the time. Otherwise the survey is only measuring the density of calling pairs not the total population density.

While point count methods could also be used to census primates, they have not been commonly used instead of the mapping method. Hanya *et al.* (2003) used them to census Japanese macaque groups in mountainous terrain where transects were not feasible. Point count methods measure the distance to any calling/observed individual from randomly placed points throughout the study area. The distances are used in Distance to assess how the probability of detection declines with distance from the point. Assumptions are similar to those for line transects: (1) all animals at the point are detected, (2) measurements are exact, (3) animals do not move during the recording period, and (4) points are established randomly with respect to the primates.

A slight variation on the point count is cue counting (Buckland *et al.* 2006). In this case, each call is recorded, together with an estimate of its distance from the point. An advantage of this approach is that the method is not biased if animals are moving around during the recording period, provided the movement is unaffected by the presence of the observer. To convert an estimate of number of calls per unit area per unit time to an estimate of animal density, an estimate of the mean call rate of animals in the population is required. Distances may be difficult to estimate, and may require multiple observers at different locations to allow triangulation. Given rapid advances in acoustic technology, it may soon be feasible to establish an acoustic array at a sample point, from which distances to calling animals can be recorded; because animal movement does not generate bias, such an array may be left to record calls over an extended period. We are not aware of any primate studies that currently use cue counting methods, but we believe that they have considerable potential for some species.

A related method is to use a line transect design, but instead of walking along the transect, observers are stationed at points along the transect. These observers record calling animals, and their bearing from the point, together with the exact time of each call. Distances of calling animals from the line are then found by triangulation, after matching calls from the same individual recorded by different observers (B. Rawson pers. comm.).

2.6.2 Lure counts

Lure counts differ from simply mapping calling primates by actively luring the animals by playing a call that attracts them. In the case of primates this is usually a call of another group of the species under study (for other species, distress calls of prey animals can also be used). A detection function is developed by testing the playback of the call at different distances from a sample of primate groups whose location is known, from which a model for the detection function is fitted using logistic regression; this function represents the probability that an individual will be detected from the point at which the lure is played. This detection function model is then assumed to hold for the main survey, where a lure is played at each of a number of points systematically spaced through the survey region. The method uses a similar approach to point counts where the detection function is used to estimate an effective radius of response and area searched at each play back point. Once this area is known, the number of responding groups can be converted to a density estimate (Buckland*et al.* 2006). A variation of this method was used by Savage *et al.* (2010) where observers moved along parallel transects playing lure calls for cotton-top tamarins (*Saguinus oedipus*) and luring animals from the strip between the transects. The parallel transects were close enough to be sure that all groups located between the transects would respond, and the direction of approach allowed the observers to determine which of the detected groups were initially located between the two transects.

2.7 Measurements of relative abundance and occupancy

In certain cases it may only be possible to obtain estimates of relative density. This is often for reasons of cost rather than because it is not possible to estimate absolute density, although if one of the assumptions of the method is broken then relative density may be all that can be estimated. Encounter rates of primates along transects can be a measure of relative density but will vary with detectability of the animals, which in turn varies according to many factors, including observer, habitat, animal behavior, group size, and season. Distance sampling methods allow estimation of the probability of detection with distance from the transect (and with other covariates, using the mcds engine of Distance) and so can correct encounter rates for detectability. However, establishing transects can be costly and in some environments attracts poachers. More ground can be covered with reconnaissance walks that aim to follow a compass direction but move around obstacles rather than cut a transect through them. Reconnaissance walks (recce walks) are biased and only encounter rates can be obtained using this method. However, several studies have found good correlations between encounter rates from recce walks and density (e.g., Plumptre and Cox 2005 for chimpanzee nests; Walsh and White 1999 for elephant dung). Encounter rates from recces can therefore be used to estimate density in some areas where resources are limited provided the same correlation holds true. Helicopter surveys of orangutan nests also found a good correlation between the density of canopy nests counted and estimates of orangutan density from ground surveys using line transect techniques, so that aerial counts of relative abundance can be corrected to estimate total abundance (Ancrenaz *et al.* 2005).

Relative measures of abundance assume that detectability does not vary. Hence they should only be used if it is not possible, or if it is prohibitively expensive, to estimate detectability and hence population density.

2.7.1 Occupancy analysis

Occupancy analysis can be used to assess the probability that a primate species is present at a particular site for rare species. This method does not usually allow estimation of primate abundance, although it can in some cases (Royle and Nichols 2003). It is most useful for rare species where the sample sizes would be too small to estimate density using line transect analyses (for some nocturnal species, for instance). In order to undertake an occupancy analysis, several visits to the sites need to be made over a particular survey period. Sites need to be established in a random manner with respect to the primate species, as in any random survey design, and can be points where point counts can take place or short transects. The presence or absence of the species at each site is recorded on each visit. The analysis method calculates the detection probability of the species being surveyed, which makes it a more suitable method to use than encounter rates when monitoring a species. It is not possible to give details about occupancy analysis here but the methods are summarized well in Mackenzie *et al.* (2006) and the accompanying website is useful (Donovan and Hines 2007). We are only aware of the use of occupancy analysis in two primate studies (Neilson 2010; Keane *et al.* 2012) but it has been used widely for other species and would be appropriate for certain rare and elusive primates.

2.8 Nocturnal primates

Line transect methods can be used for nocturnal primates where the assumptions listed in Section 2.5 are met. This method is most often used with lorises (Nekaris *et al.* 2008) and sometimes with galagos as well. For other nocturnal primates that are rarely encountered, the line transect method is not ideal (Duckworth 1998) and